CLAIMS

What is claimed is:

1. A reactor for the production of nanoparticles in an aerosol process comprising:

(a) a reaction chamber having a wall, an inlet and an outlet the inlet for introducing a hot carrier gas to the reaction chamber which hot carrier gas flows from the inlet through the reaction chamber and out the outlet,

(b) a quench zone located downstream of the reaction chamber having an inlet and an outlet,

(c) one or more quench inlets being positioned approximately about the outlet of the reaction chamber for introducing a quench material,

(d) one or more reactant inlets positioned between the reaction chamber inlet and the quench inlets for introducing one or more reactants;

the reaction chamber comprising: (i) a spacer zone having a length, L_1, extending from the reaction chamber inlet and ending approximately about the reactant inlets and (ii) a homogenization zone having a length L_2 extending from approximately the location of the reactant inlets and ending approximately about the quench zone inlet; the spacer zone for allowing the hot carrier gas to carry the reactants to the homogenization zone, the homogenization zone for contacting the reactants under conditions suitable for forming a reaction product and passing the reaction product to the quench zone, L_1 being sufficient for the hot carrier gas to attach to the wall of the spacer zone of the reaction chamber prior to the reactant inlets and L_2 being sufficient for a residence time of the reactants within the homogenization zone suitable for forming the reaction product which when withdrawn from the outlet of the quench zone is a nanoparticle.

2. The reactor of Claim 1, which further comprises a high temperature heating means for heating the carrier gas selected from the group consisting of a DC plasma arc, RF plasma, electric heating, conductive heating, flame reactor and laser reactor.

3. The reactor of Claim 1, which further comprises a DC plasma arc for heating the carrier gas.

4. The reactor of Claim 1, which further comprises an RF plasma for heating the carrier gas.

5. The reactor of Claim 1, wherein the reaction chamber further comprises a homogenizer which provides the spacer zone and the homogenization zone.

6. The reactor of Claim 5, wherein the homogenizer is constructed of copper or ceramic material.

7. The reactor of Claim 5, wherein the homogenizer has a wall, an entrance and an exit, the homogenizer wall converging to a nozzle tip at the exit which is spaced a distance $L_1 + L_2 + L_3$ from the entrance.

8. The reactor of claim 7 in which the distance L_3 is zero.

9. An aerosol process for producing nanosize particles, comprising:

(a) introducing a hot carrier gas into an aerosol reactor, the aerosol reactor comprising a reaction chamber and a quench zone having an inlet and an outlet, the reaction chamber having a wall, a carrier gas inlet and an outlet, one or more quench material inlets being positioned approximately about the outlet of the reaction chamber, one or more reactant inlets positioned between the carrier gas inlet and the quench material inlets; the reaction chamber having: (i) a spacer zone having a length, L_1, extending from the reaction chamber inlet and ending approximately about the reactant inlets and (ii) a homogenization zone having a length L_2 extending from approximately the location of the reactant inlets and ending approximately about the quench zone inlet; wherein the hot carrier gas is introduced to the reaction chamber at the carrier gas inlet, the hot carrier gas flowing through the reaction chamber and out the outlet into the quench zone;

(b) introducing one or more reactants into the reaction chamber at the reactant inlets, the reactants contacting the hot carrier gas in the spacer zone and passing to the homogenization zone to form a reaction product, L_1 being sufficient for the hot carrier gas to attach to the wall of the spacer zone of the reaction chamber prior to the reactant inlets and L_2 being sufficient for a residence time of the reactants within the homogenization zone suitable for forming the reaction product;

(c) passing the reaction product to the quench zone; and

(d) withdrawing from the outlet of the quench zone a nanoparticle reaction product.

10. The process of Claim 9, wherein the reactants are $TiCl_4$ and O_2 and the product is TiO_2 particles.

11. The titanium dioxide particles of Claim 10 having a particle size of between 10 nm and 100 nm and a BET surface area of more than $10 m^2/g$.

12. The process of Claim 9, wherein the carrier gas is inert.

13. The process of Claim 9 wherein the carrier gas is selected from the group consisting of argon, oxygen, nitrogen, and a combination thereof.

14. The process of Claim 9, wherein the reactants are one or more precursor materials.

15. The process of Claim 9, wherein the reactants are in the vapor, liquid, emulsion, dispersion, solution or powder form.

16. The process of Claim 9, wherein the carrier gas is introduced to the reaction chamber so that it has a flow direction axially from the chamber inlet downstream through the reaction chamber.

17. A reaction chamber for minimizing flow recirculation in a reactor, the reaction chamber comprising a wall, an entrance and an exit wherein, in the vicinity of the exit, the wall of the homogenizer converges to a nozzle tip from which a reaction product can be withdrawn, a hot carrier gas inlet located about the entrance of the reaction chamber and quench material inlets located about the exit of the reaction chamber and one or more reactant inlets located between the hot carrier gas inlet and the quench inlets, the homogenizer having (i) a spacer zone having a length, L_1, extending from the reaction chamber entrance and ending about the reactant inlets and (ii) a homogenization zone having a length L_2 extending from the reactant inlets to a position downstream of the quench inlets for contacting the hot carrier gas and the reactants and wherein L_1 of the spacer zone is sufficient for the hot carrier gas to attach to the wall of the reaction chamber before the hot carrier gas reaches the reactant inlets and L_2 of the reaction chamber being sufficient for a residence time within the homogenization zone suitable for forming the reaction product.

18. A reactor for the production of nanoparticles from an aerosol process comprising:

(a) a reactor chamber having axially spaced inlet and outlet ends along the reactor axis wherein positioned at the inlet end of the reactor chamber is a high temperature heating means to heat a carrier gas having a flow direction axially from the reaction chamber inlet downstream through the reaction chamber and out the chamber outlet and wherein one or more quench gas inlets are positioned up stream from the outlet end of the reactor chamber for introducing a quench gas for cooling;

(b) a reaction chamber having an axially spaced entrance and an exit wherein in the vicinity of the exit, the homogenizer converges to a nozzle tip, the entrance of the homogenizer being aligned with the inlet to the reaction chamber and the homogenizer being inserted within the reaction chamber and held in place by a homogenizer holder such that the homogenizer extends from the inlet end of the reaction chamber securely fitting against the inlet end for at least a portion of the homogenizer's overall length and wherein the homogenizer comprising two zones: (i) a spacer zone having a length, L_1, extending from the reaction chamber chamber entrance and ending where one or more reactant inlet tubes are positioned, after having passed through a wall of the reaction chamber, to deliver one or more reactants into the reaction chamber so the reactants contact the hot carrier gas and (ii) a homogenization zone extending from the reactant inlet tubes' location to a position down stream of the quench gas inlets; and wherein carrier gas and reactants mix and react in the homogenization zone and pass through the flow homogenization exit nozzle to enter a quench zone of the reaction chamber defined by the quench gas inlet location in a reaction chamber wall and the reaction chamber outlet and wherein L_1 of the spacer zone must be long enough to have the hot gas flow attached to walls of the reaction chamber before the hot gas reaches the reactant inlets and the overall length (L_1 + L_2) of the reaction chamber is designed to a residence time sufficient that the following three tasks are completed

before gas flow exiting the homogenizer: (1) gas flow in the reaction chamber has achieved a near one-dimensional flow and concentration profile; and (2) gas-phase nucleation of product particles has been initiated.

19. An aerosol process for producing nanosize particles, comprising the steps:

(a) introducing a carrier gas into a reactor chamber having (i) axially spaced inlet and outlet ends along the reactor axis wherein positioned at the inlet end of the reactor chamber is a high temperature heating means to heat a carrier gas having a flow direction axially from the reaction chamber inlet downstream through the reaction chamber and out the chamber outlet and wherein one or more quench gas inlets are positioned up stream from the outlet end of the reactor chamber for introducing a quench gas for cooling; and (ii) a reaction chamber having an axially spaced entrance and an exit wherein in the vicinity of the exit, the homogenizer converges to nozzle tip, the entrance of the homogenizer being aligned with the inlet to the reaction chamber and the homogenizer being inserted within the reaction chamber and held in place by a homogenizer holder such that the homogenizer extends from the inlet end of the reaction chamber securely fitting against the inlet end for at least a portion of the homogenizer's overall length and wherein the homogenizer comprising two zones: (i) a spacer zone having a length, L_1, extending from the reaction chamber chamber entrance and ending where one or more reactant inlet tubes are positioned, after having passed through a wall of the reaction chamber, to deliver one or more reactants into the reaction chamber so the reactants contact the hot carrier gas and (ii) a homogenization zone extending from the reactant inlet tubes' location to a position down stream of the quench gas inlets; and wherein carrier gas and reactants mix and react in the homogenization zone and pass through the flow homogenization exit nozzle to enter a quench zone of the reaction chamber defined by the quench gas inlet location in a reaction chamber wall and

the reaction chamber outlet and wherein L_1 of the spacer zone must be long enough to have the hot gas flow attached to walls of the reaction chamber before the hot gas reaches the reactant inlets and the overall length (L_1 + L_2) of the reaction chamber is designed to a residence time sufficient that the following three tasks are completed before gas flow exiting the homogenizer: (1) gas flow in the reaction chamber has achieved a near one-dimensional flow and concentration profile; and (2) gas-phase nucleation of product particles has been initiated;

(b) heating the carrier gas by thermal contact with the heating means to a temperature to initiate reaction of the carrier gas with one or more reactants;

(c) introducing one or more reactants through the reactant inlet tubes to form a reaction mixture;

(d) adjusting flow rates of the carrier gas and reactants such that reaction mixture flows through the flow homogenization chamber at a rate such that (1) flow of the reaction mixture is characterized by one-dimensional flow and a one-dimensional concentration profile; and (2) gas-phase nucleation of the product has been initiated;

(e) immediately injecting quench gas through the quench gas inlet tubes as the reaction mixture flow enters the quench zone so that particle coagulation and coalescences is reduced and temperature of the reaction mixture and product is decreased; and

(f) separating and collecting the product.

20. A reaction chamber for minimizing flow recirculation in a reactor, the reaction chamber comprising an axially spaced entrance and an exit wherein in the vicinity of the exit the homogenizer converges to nozzle tip, the entrance of the homogenizer being aligned with the inlet to the reaction chamber and the homogenizer being inserted within the reaction chamber and held in place by a homogenizer holder such that the homogenizer extends from the inlet end of the reaction chamber securely fitting against the inlet end for at least a portion of the homogenizer's overall length and wherein the homogenizer comprising two zones: (i) a spacer zone having a length, L_1, extending from the reaction chamber

chamber entrance and ending where one or more reactant inlet tubes are positioned, after having passed through a wall of the reaction chamber, to deliver one or more reactants into the reaction chamber so the reactants contact the hot carrier gas and (ii) a homogenization zone extending from the reactant inlet tubes' location to a position down stream of the quench gas inlets; and wherein carrier gas and reactants mix and react in the homogenization zone and pass through the flow homogenization exit nozzle wherein L_1 of the spacer zone must be long enough to have the hot gas flow attached to walls of the reaction chamber before the hot gas reaches the reactant inlets and the overall length ($L_1 + L_2$) of the reaction chamber is designed to a residence time sufficient that before gas flow exits the homogenizer: gas flow in the reaction chamber has achieved a near one-dimensional flow and concentration profile.